Photo courtesy of Syngenta Seeds, Inc.

Genetically Engineered Crops

U.S. Adoption & Impacts

Since the introduction of genetically engineered (GE) crops in 1996, U.S. farmers have rapidly adopted most of them, notwithstanding conflicting claims about economic and environmental impacts and consumer acceptance. Soybeans and cotton with herbicide-tolerant traits have been the most widely and rapidly adopted GE crops in the U.S., followed by insect-resistant cotton and corn.

Analyses by USDA's Economic Research Service (ERS) and others indicate economic benefits to many farmers adopting first-generation GE crops. Not all benefits are reflected in standard measures of net returns. (See following article.)

Extent of GE Crop Adoption

Herbicide-tolerant (HT) crops, developed to survive application of specific herbicides that previously would have destroyed the crop along with the targeted weeds, provide farmers with a broader variety of options for effective weed control. Based on USDA survey data, **HT soybeans** expanded from 17 percent of U.S. soybean acreage in 1997, to 68 percent in 2001 and 75 percent in 2002. Plantings of **HT cotton** expanded from 10 percent of U.S. acreage in 1997 to 56 percent in 2001 and 58 percent in 2002. The adoption of **HT corn**, however, has been much slower, barely exceeding 10 percent of U.S. corn acreage in 2002.

Insect-resistant crops containing the gene from the soil bacterium Bt (*Bacillus thuringiensis*) have also been available for corn and cotton since 1996. These bacteria produce a protein that is toxic to certain lepidopteran insects (insects that go through a caterpillar stage), protecting the plant over its entire life.

Plantings of **Bt corn** grew from 8 percent of U.S. corn acreage in 1997 to 26 percent in 1999, then fell to 19 percent in 2000 and 2001, before climbing back to 24 percent in 2002. Plantings of **Bt cotton** expanded more rapidly, from 15 percent of U.S. cotton acreage in 1997 to 37 percent in 2001, but adoption appears to be leveling off, as U.S. farmers planted 35 percent in 2002. Use of Bt corn will likely continue to fluctuate over time, based on expected infestation levels of European Corn Borer (ECB). Similarly, adoption of Bt cotton is based on expected infestation of Bt target pests. Adoption appears to have reached the low-growth phase, as adoption has already occurred on acreage where Bt protection is most needed. Insects have not posed major problems for soybeans, so insect-resistant varieties have not been developed.

Some farmers have adopted "stacked" varieties of cotton and corn that have both HT and Bt traits. Stacked cotton reached 24 percent of cotton plantings in 2001, dropping slightly to 22 percent in 2002. Plantings of stacked corn are much lower, making up only 2 percent of corn acres in 2002.

Total adoption of GE cotton, taking into account the acreage with either or both HT and Bt traits, reached 71 percent in 2002, slightly lower than that for soybeans at 75 percent. In contrast, adoption of GE corn in total was 33 percent.

Factors in GE Crop Adoption

Adoption of HT soybeans has occurred uniformly across all farm sizes. This might be expected, since GE crop technologies require changes only in variable inputs (such as seeds), which are completely divisible (unlike machinery, they may be purchased as needed).

What Is Genetic Engineering?

Genetic engineering is, very broadly, a technique used to alter or move genetic material (genes) of living cells to create, improve, or modify plants, animals, and microorganisms. Narrower definitions are used by agencies that regulate genetically engineered organisms. In the U.S., under guidelines issued by USDA's Animal and Plant Health Inspection Service, genetic engineering is defined as "the genetic modification of organisms by recombinant DNA techniques." Definitions used in Europe are somewhat broader.

Using conventional techniques, such as selective breeding, scientists have been working to improve plants and animals for human benefit for hundreds of years. Genetic engineering techniques now enable scientists to move genes (and therefore desirable traits) in ways not possible before, and with greater ease and precision.

However, adoption of HT and Bt corn has occurred more often on larger farms. For HT corn, this is attributed to its low overall adoption rate, which implies that adopters were largely innovators and other early adopters. Adoption is more responsive to farm size at the innovator stage and this effect generally diminishes as diffusion increases. In the case of Bt corn, larger farms may be adopting more frequently because Bt corn targets a pest problem that is generally most severe in areas where operations growing corn are largest, such as the western Corn Belt and Great Plains.

GE crop adoption is positively and significantly related to operator education, experience, or both. More educated or experienced operators are more likely to understand that the greatest economic benefits of new technologies generally accrue to early adopters. Use of marketing or production contracts is positively associated with GE crop adoption, possibly reflecting the greater importance placed on risk management by adopting farms. Contracting ensures the adopter a market for the GE crop, reducing price and any market access risk.

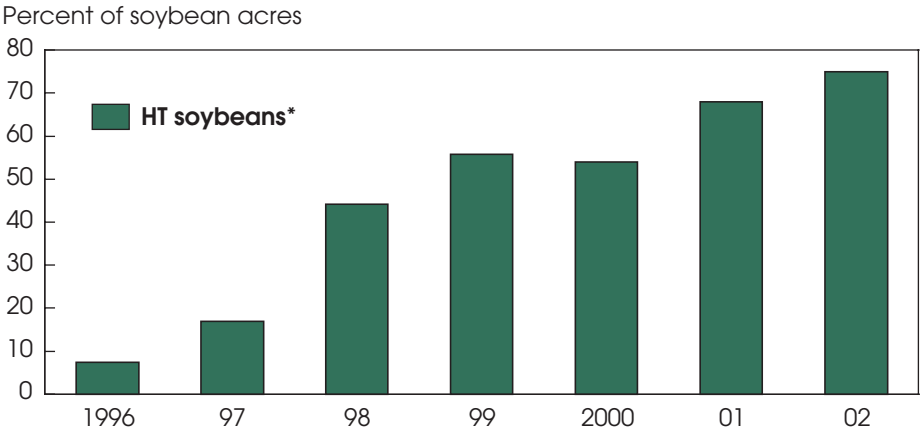
The Impacts of Adoption

The impacts of GE crop adoption on U.S. farmers vary by crop and technology. GE crops potentially benefit U.S. farmers through yield gains over conventional varieties or through savings in insecticide/herbicide costs. In addition, HT soybeans and cotton are relatively simple to use, increase flexibility in timing herbicide applications, and fit in well with conservation tillage and other production systems. While these latter benefits have an economic value in terms of saving farmers' own labor and management time, this value is difficult to measure and has not yet been incorporated into impact estimates.

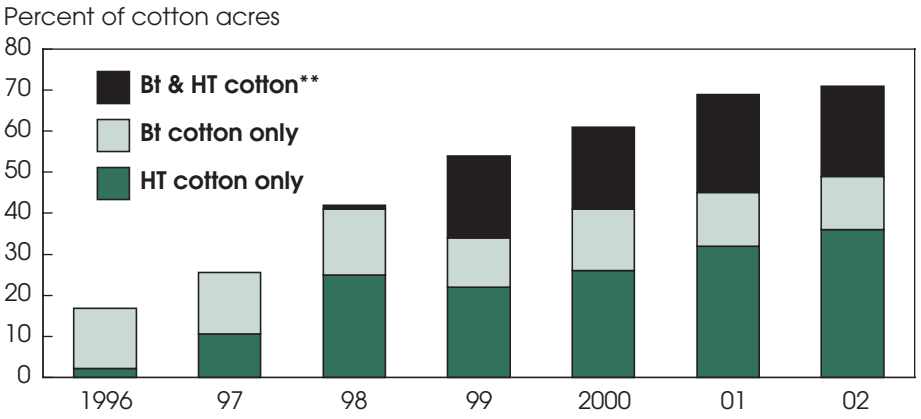
Various studies have examined the impacts of GE crop adoption. ERS analyses for 1997-98, based on data from the Agricultural Resource Management Survey (ARMS), are highlighted below.

Planting HT cotton and corn increased producer net returns. ERS analyses found yields higher, pesticide use lower, and net returns higher with HT cotton and

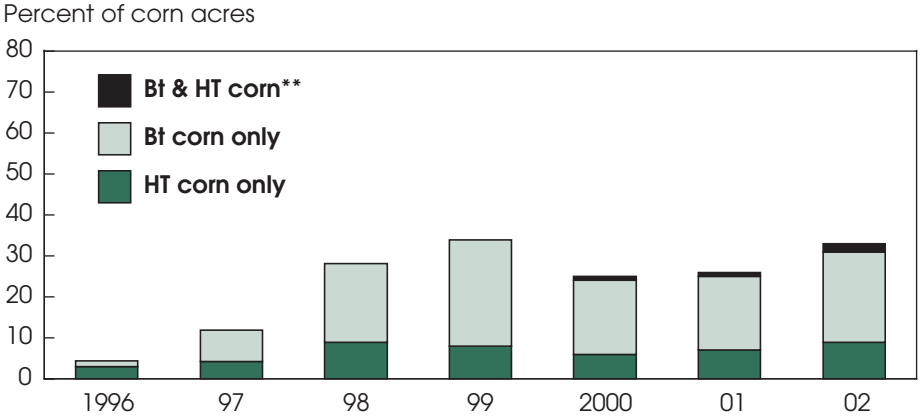
Adoption of Gentically Engineered Soybeans Has Reached 75 Percent. . .



. . .and GE Cotton Adoption Exceeds 70 Percent. . .



. . .while GE Corn Adoption Stands at 34 Percent



Planted acreage.
HT=herbicide-tolerant. Bt denotes insect-resistant crops containing the gene from a soil bacterium, *Bacillus thuringiensis*.
*Insect-resistant varieties have not been developed for soybeans, since insects have not posed a major problem for that crop.
**Estimated for 1998 and 1999.

Economic Research Service, USDA

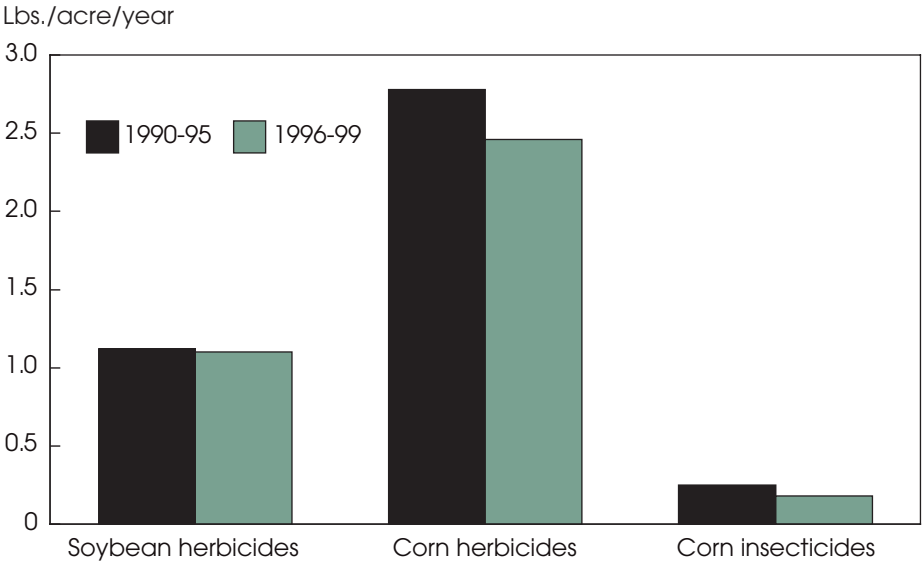
corn, compared with conventional varieties. Despite the positive impact on net returns, production and marketing factors may be contributing to the stagnant growth in adoption of HT corn. The limited acreage on which HT corn has been used is likely the acreage with the greatest comparative advantage for this technology. Limited adoption of HT corn compared with HT soybeans and cotton may be due in part to constraints imposed on corn-soybean rotations (such as "volunteer" corn growing in soybean fields because it tolerates the applied herbicide). Also, some HT corn varieties so far have limited approval and consumer acceptance outside the U.S., restricting their export market potential.

Adoption of Bt cotton and corn increases returns when pest pressures are high. Adoption of Bt cotton had a positive impact on producer net returns in 1997, but the impact was negative for Bt corn in 1998. This suggests that Bt corn may have been planted on some acreage where the value of protection against the ECB was lower than the premium paid for the Bt seed.

Pest infestations differ across the country (for example, ECB infestations are more frequent and severe in the western Corn Belt), and the economic benefits of Bt corn are greatest where target pest pressures are most severe. The decision to use Bt corn is complicated, because damage caused by the ECB varies from year to year and because the decision must be made before observing the ECB pest pressure. Thus, some farmers may have overestimated infestation levels, yield losses, and corn prices, resulting in "overadoption." Also, some producers plant Bt corn because it reduces the risk of significant losses due to pest damage, a factor not explicitly included in ex-post net returns calculations.

HT soybeans did not significantly affect farmers' net farm returns in 1997 or 1998. The crop has been profitable for some farms, depending on the types of weed problems on the farm. But for other farms, factors such as simplicity and flexibility may be driving adoption—factors that allow the use of one product instead of several herbicides to control a wide range of both broadleaf and grass weeds, making harvest "easier and faster." Such benefits are not reflected in standard measures of net returns to farming.

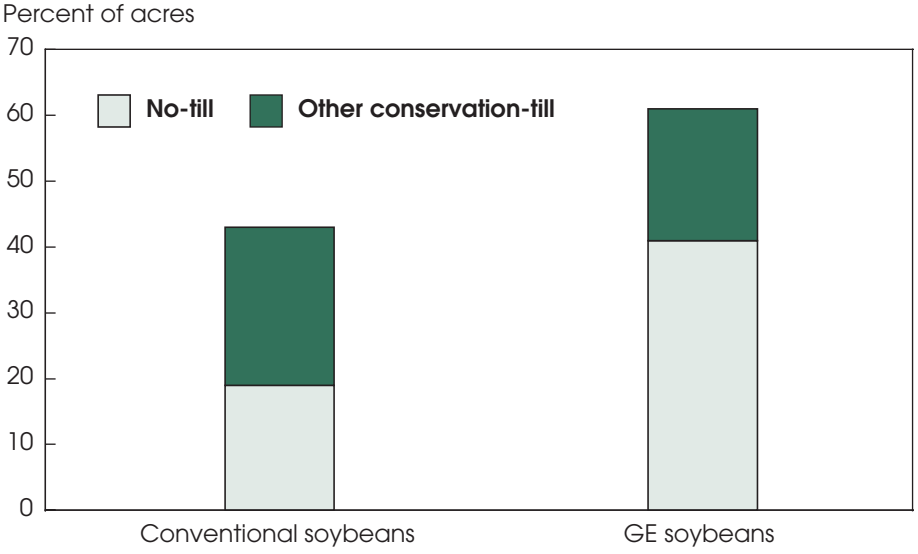
Pesticide Use on Corn Has Dropped Since Advent of GE Varieties in 1996



Insect-resistant varieties have not been developed for soybeans, since insects have not posed a major problem for that crop.
Source: USDA's Agricultural Resource Management Survey (ARMS).

Economic Research Service, USDA

Conservation Tillage Use Is Higher on Acreage in GE Soybeans Than in Conventional Varieties



Source: USDA's 1997 Agricultural Resource Management Survey (ARMS).

Economic Research Service, USDA

Pesticide use has changed and declined, benefiting the environment. Pesticide use on corn and soybeans has declined since the introduction of GE corn and soybeans in 1996. Planting Bt varieties

ERS Study on Adoption of GE Crops

Issues related to the adoption of GE crops—including farm impacts, consumer acceptance, environmental safety, and others—are among the leading concerns affecting U.S. agriculture. Because of the controversy surrounding these issues and the continual introduction of new technologies, a need exists for objective measurement and analysis of all social welfare implications of GE crops, including farm-level impacts.

USDA's Economic Research Service (ERS) has studied GE crops and their adoption by farmers since 1998. The farm-level component of this research program used econometric methods and data obtained from surveys conducted by USDA to address the following three questions.

- What is the extent of adoption of GE crops and their diffusion path?
- What factors have affected the adoption of GE crops and how?
- And finally, what are the farm-level impacts of the adoption of GE crops?

The GE crops considered here include those with herbicide-tolerant and insect-resistant traits—the principal GE crops available to and adopted by U.S. farmers. This article summarizes the findings of the recent ERS report ***Adoption of Bioengineered Crops***, AER 810, May 2002 (www.ers.usda.gov/publications/aer810/).

has led to reductions in insecticides previously used to treat the pests targeted by Bt. However, use of conventional insecticides targeting other insects has not been affected. Adoption of herbicide-tolerant crops involves substitution of a particular herbicide (such as glyphosate) for others, changing the mix of herbicides used in the cropping system.

Field tests and enterprise studies have analyzed the agronomic, environmental, and economic effects of adopting GE crops, including actual changes in pesticide use associated with using GE crops. Many of these studies have shown that insecticide use declines with the adoption of Bt varieties and that herbicide use is reduced with herbicide-tolerant varieties.

ERS analysis, using an econometric model that statistically controls for other factors affecting pesticide use, shows an overall reduction in pesticide use (including insecticides and herbicides) associated with the increased adoption of GE crops (Bt cotton, and herbicide-tolerant corn, cotton, and soybeans; Bt corn data were not available). The decline in total pesticide use between 1997 and 1998 on U.S. corn, soybeans, and cotton was estimated to be 19.1 million acre-treatments, or 6.2 percent of total treatments. Total active ingredients applied to corn, soybean, and cotton fields also declined by about 2.5 million pounds, resulting in a significant reduction in potential exposure to pesticides.

The amount of herbicide active ingredient applied to soybeans increased slightly because the additional amount of glyphosate applied to HT soybeans exceeded the reduction in other types of soybean herbicides. However, glyphosate has a lower toxicity to mammals, birds, and fish; binds to the soil rapidly, preventing leaching; and is easily biodegraded by soil bacteria. Glyphosate is only a third as toxic to humans and is likely to persist in the environment for only half as long as the herbicides it displaces.

HT crops may indirectly benefit the environment by encouraging adoption of conservation tillage. Nearly 60 percent of the area planted with HT soybeans in 1997 was under conservation tillage, which reduces soil erosion, soil degradation, and runoff. In comparison only 40 percent of soybean acres planted with conventional varieties was under conservation tillage. Differences in the use of no-till between adopters and nonadopters of HT soybeans were even more pronounced. Of acres planted with HT soybeans, 40 percent were under no-till (where weed control is fully dependent on herbicides), twice the corresponding share for farmers planting conventional soybeans.

Analyses of impacts will continue. ERS analyses of impacts are based on just 2 years of survey data: 1997 and 1998. The extent and impacts of GE crops vary with several factors, most notably annual pest infestations, seed premiums, prices of alternative pest control programs, and any premiums paid for segregated crops. These factors will continue to change over time as the technology, marketing strategies for GE crops, and consumer perceptions evolve. ERS will continue to provide information on the evolution, as well as the impacts on farmers, consumers, and the environment. Future surveys and analyses will attempt to evaluate the most widely touted farmer benefits of HT seeds—simplicity and flexibility of use and management—that are not captured by the standard measurement of net returns. AO

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For further information

Acreage data available from the USDA's National Agricultural Statistics Service (NASS)
http://usda.mannlib.cornell.edu/reports/nassr/field/pcp-bba/acrg0602.pdf

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